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Review on IoT-Based Smart Mining Safety and Surveillance Robot

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Abstract:
Mining environments present serious safety challenges due to unstable geological structures, fluctuating temperatures, and the possible accumulation of harmful gases. Human inspection in such conditions increases exposure to life-threatening risks. This review discusses the design and working principles of an IoT-integrated Unmanned Ground Vehicle (UGV) referred to as "MINING-BOT." The system combines remote teleoperation, environmental sensing, and cloud-based monitoring to support safer underground inspection. Emphasis is placed on communication reliability, sensor integration, and real-time data transmission as key elements for improving operational safety in mining sectors.

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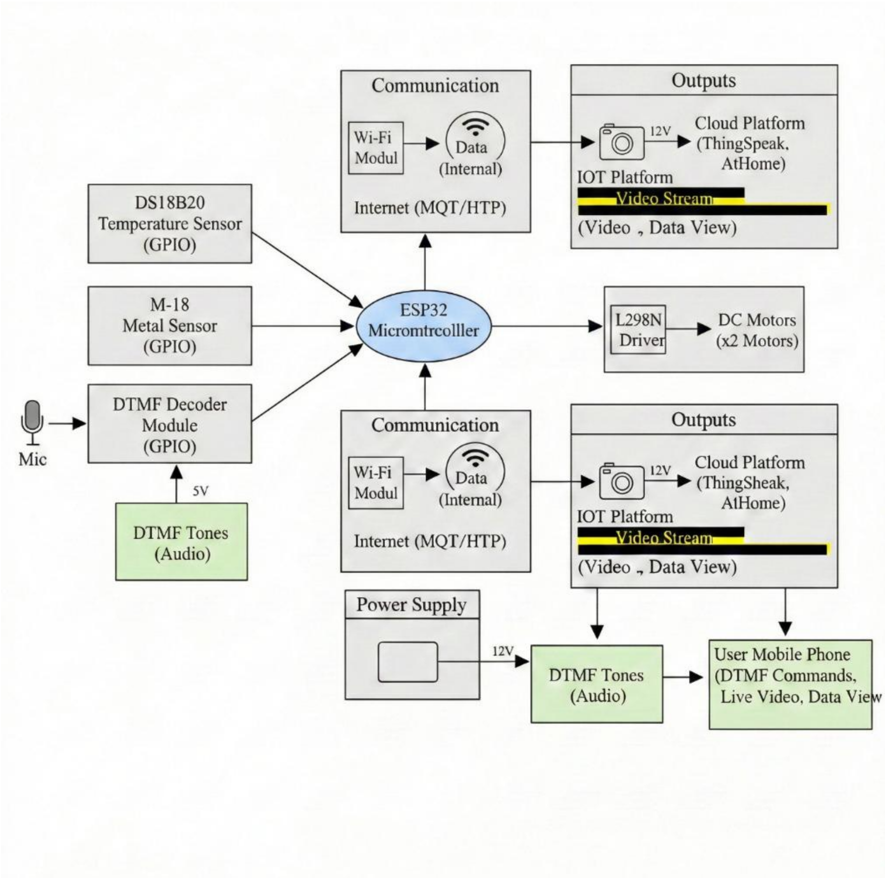
I. Introduction:

Mining continues to play a critical role in global industrial development, yet it remains one of the most dangerous occupations. Many accidents occur due to delayed detection of hazardous conditions such as structural instability or sudden environmental changes. Conventional inspection methods often require personnel to enter high-risk zones before safety confirmation.

To address this limitation, robotic systems can serve as preliminary inspection agents. The proposed MINING-BOT operates as a remotely controlled exploration unit capable of entering tunnels before human workers. By transmitting environmental data and live visuals to operators, the system reduces direct human exposure while enabling informed decision-making.

Block Diagram 1: System Architecture



II. Literature Survey:

Research in mining robotics and underground monitoring highlights several technological foundations relevant to this system.
Studies on communication methods for underground robotics indicate that traditional wireless systems such as Wi-Fi and Bluetooth suffer from range limitations and signal attenuation in deep tunnels. Alternative approaches using Dual-Tone Multi-Frequency (DTMF) signalling have demonstrated improved reliability in environments where conventional RF communication becomes unstable. DTMF-based control utilizes cellular infrastructure, which enhances long-distance operability.
Wireless Sensor Network (WSN) implementations in underground monitoring systems have shown that distributed sensing nodes can assist in predicting hazardous environmental changes. Research from technical institutions has validated the use of temperature and air-quality sensors for early hazard detection, supporting the integration of similar sensors in robotic platforms.
Foundational literature on autonomous mobile robotics provides theoretical models for navigation, terrain adaptation, and obstacle detection. These principles ensure that unmanned vehicles maintain balance and control in uneven and confined environments such as mining tunnels.
Further studies in mining safety engineering emphasize the reduction of worker "exposure duration" to toxic gases such as methane and carbon monoxide. Robotic substitution for preliminary inspections directly contributes to lowering such exposure.

Proposed System:
The proposed MINING-BOT consists of a multi-layer architecture integrating control, sensing, communication, and mobility components.

Control System
The robot operates using DTMF-based teleoperation. Commands are transmitted through a mobile device keypad and decoded by the onboard system. This method maintains communication even in signal-restricted underground zones.

Processing Unit
An ESP32 microcontroller acts as the central processing unit, managing sensor data acquisition, motor control, and IoT communication.

Sensing Layer
Environmental monitoring is performed using:

- DS18B20 sensor for accurate temperature measurement
- M-18 inductive sensor for metal detection

These sensors provide real-time environmental feedback necessary for safety evaluation.

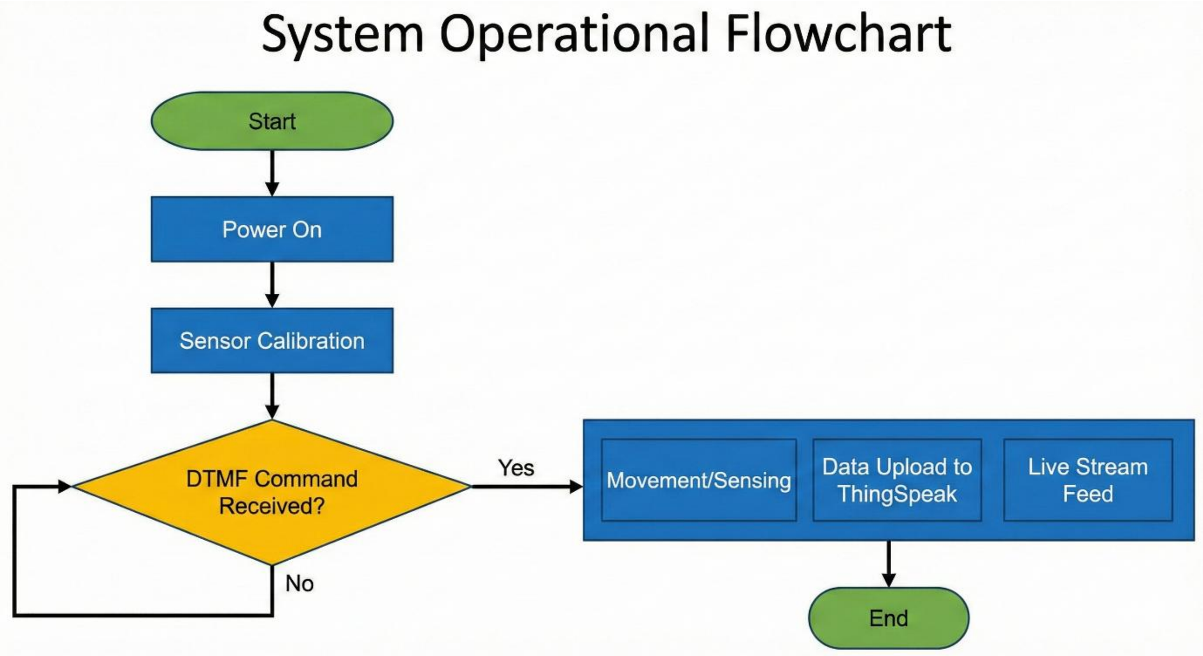
Communication and Monitoring

Live visual transmission is enabled through an integrated streaming module. Simultaneously, environmental parameters are uploaded to a cloud-based IoT platform such as ThingSpeak for remote monitoring and historical data analysis.

Mechanical Structure

The robotic chassis is powered by high-torque DC motors controlled through an L298N motor driver. This configuration supports movement across rough and inclined mine surfaces.

Block Diagram 2: Operational Flow



III. Conclusion:

The implementation of an IoT-based surveillance robot offers a practical approach to enhancing underground mining safety. By delegating initial inspection tasks to an unmanned system, direct human exposure to hazardous conditions can be minimized. The integration of DTMF communication ensures reliable remote operation, while IoT connectivity enables continuous environmental monitoring.

Future developments may include integration of advanced gas sensors, improve autonomous navigation algorithms, and expand predictive analytics capabilities. Such enhancements would further strengthen the role of robotic systems in industrial safety applications.

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